*IN THE UNITED STATES PATENT AND TRADEMARK OFFICE*

In re application of: Wu et al.

Application No.: 10/820,525

Filed: April 7, 2004

Title: METHODS FOR PRODUCING LOW-K CDO FILMS WITH LOW RESIDUAL STRESS

Attorney Docket No.: NOVLP091/NVLS-2889

Examiner: Maldonado, Julio J.

Group: 2823

***DECLARATION UNDER 37 CFR § 1.131***

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

We, Qingguo Wu, Haiying Fu, Dong Niu, Ananda Banerji (née Bandyopadhay) and David Mordo declare as follows:

CONCEPTION

1. Prior to April 11, 2003, we invented the subject matter claimed in the patent application cited above. Specifically, we conceived the invention in the United States before that date. In addition, Qingguo Wu, Haiying Fu and Dong Niu drafted an "Invention Priority Data and Information" document describing the invention. This document is attached as Exhibit A and it was prepared prior to April 11, 2003. The specific dates evidencing conception and other confidential information have been redacted from this document.

2. As shown, the "Invention Priority Data and Information" document (Exhibit A) describes producing low-k carbon-doped oxide (CDO) films having low stress.

Regarding independent claims 1, 19 and 29, please see the "Abstract" and "Technical Contents." Of particular relevance, see "Process Optimization" on pages 7 and 8, in which forming a CDO film having < 35 MPa and a k < 3.0 is described.

DILIGENCE

Attached Exhibits A-H show the diligent pursuit of the completion of the invention from a time just prior to the effective date of the cited prior art (April 11, 2003) to the time of filing of the application (April 7, 2004).

3. During the period April 11, 2003 – August 4, 2003, we were conducting experiments and research to reduce the invention to practice. Amongst other aspects of the invention, we researched process conditions and precursors to obtain the low stress films.

4. Exhibit B is a written report submitted to Haiying Fu by Qingguo Wu showing diligence in reducing the invention to practice during this period. Specifically, Exhibit B is a report dated June 25, 2003 that shows work done on low stress films. An electronic version of this document was located at Novellus and accessed by Qingguo Wu in February 2009. Confidential information has been redacted from this document.

5. Exhibit A is the "Invention Priority Data and Information" document drafted by Qingguo Wu, Haiying Fu and Dong Niu. It was drafted on August 4, 2003 and received by the Novellus Legal Department on August 18, 2003. The specific dates evidencing conception and other confidential information have been redacted from this document. A copy of this document was located in the attorney file for this case.

6. Exhibit C is a copy of a letter from Roland Tso of the Novellus Legal Department to Jeffrey Weaver dated September 22, 2003. The letter shows pursuit of filing a

patent application for this case (NVLS-2889). A copy of this document was located in the attorney file for this case.

7. During the period August 2003 – December 2003, we continued to conduct experiments and research to diligently reduce the invention to practice. Amongst other aspects of the invention, we researched process conditions and precursors to obtain the low stress films.

8. Exhibits D-F are written reports submitted to Haiying Fu by Qingguo Wu showing diligence in reducing the invention to practice during this period. Specifically, Exhibits D-F are reports dated October 29, 2003; November 11, 2003; and December 3, 2003, respectively, that show work done on low stress films. Electronic versions of these documents were located at Novellus and accessed by Qingguo Wu in February 2009. Confidential information has been redacted from these documents.

9. On December 8, 2003, Haiying Fu had a telephone conference with Jeffrey Weaver and Joe Bond, a patent agent involved with drafting the application, regarding the invention disclosure and updated data.

10. During the period December 8, 2003 – March 29, 2004, Jeffery Weaver and Joseph Bond worked on drafting the application. Exhibit G is report showing all time entries by Jeffrey Weaver and Joseph Bond for preparing the patent application (Attorney Docket Number NOVLP091). The report was printed by the accounting department of the responsible law firm in February 2009. The report shows diligence is preparing the patent application during this period and indicates that several drafts were sent to inventors during for review during this period.

11. Exhibit H is a copy of a letter dated March 29, 2004 from Joseph Bond to Haiying Fu enclosing a revised draft of the application. The letter also states that changes were made to the draft based on inventor comments and encloses a declaration to be signed.

12. The application was filed on April 7, 2004.

All statements herein are based on personal knowledge or information including review of the attached exhibits. We each hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. We further declare that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both (under Section 1001 of Title 18 of the United States Code), and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Qingguo Wu — Date 2/27/09

Haiying Fu — Date 2/27/2009

Dong Niu — Date 2/27/09

Ananda Banerji (née Bandyopadhay) — Date 2/27/2009

David Mordo — Date 2/27/09

# EXHIBIT A

Return completed forms to Roland Tso M/S 280

NOVELLUS
FIRST IN PRODUCTIVITY

# INVENTION PRIORITY DATA AND INFORMATION

Docket Number: 2889 Date Received: 8/18/03

1. Title of Invention: Methods for producing Low-k OSG film of low tensile stress
2. Description of Invention: (Please attach witnessed "Invention Disclosure" forms to this one.)
3. Invention conception date: _____ REDACTED _____
4. Date of first written description of the Invention (attach copy): _____
5. First disclosed to: _____ Date: _____
6. Date of first offer for sale of product incorporating the Invention: REDACTED _____
7. Date of first or future shipment to customer (name & date): _____
8. Date of first or future publication of the Invention: _____
9. List the products which the Invention will be used in: REDACTED _____

INVENTOR(S):

1. Name: Haiying Fu Employee Number: 2434
   Work Address: 11155 SW Leveton Dr, Tualatin, OR 97062
   Work Phone Number: 503.885.6625 Fax Number: 503.612-8701
   Home Address: 22580 Clark Street, West Linn, OR 97068
   Signature: _____ Date: 8/13/03 Citizenship: USA
2. Name: QINGGUO Wu Employee Number: 5810
   Work Address: 11155 SW Loveton Dr. Tualatin, OR 97062
   Work Phone Number: 503-885-6749 Fax Number: 503-612-8701

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Home Address: 17865 SW 113th Ave. Tualatin, OR 97062

Signature: [signature] Date: 8/13/03 Citizenship: Canada

3. Name: Dong Nin Employee Number: 5905

Work Address: 11155 SW Leveton DR, Tualatin, OR 97062

Work Phone Number: 503-885-6459 Fax Number: 503-612-8701

Home Address: 18045 SW Royalty Pkwy, Apt L32, Tigard, OR 97024

Signature: [signature] Date: 8/14/03 Citizenship: China

WITNESS DECLARATION (must be signed and dated by two witnesses):

I have read and examined the above, the description on the attached disclosure forms, and I understand the subject matter described therein.

1. First Witness (print): XINGYUAN TANG

Signature: [signature] Date: 08/14/03

2. Second Witness (print): A K BANDYOPADHYAY

Signature: [signature] Date: 8/14/03

# INVENTION DISCLOSURE

Novellus Systems, Inc.

Title of Invention: **Methods for producing Low-k OSG Film of low tensile stress**

Date this form was completed: 08/04/2003 Page 1 of 8 10

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**Abstract**


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The present invention involves a chemical vapor deposition (CVD) reactor applying different deposition conditions, including process gases and process parameters, to form low-k films. The present invention relates to process optimization and improvement, through precursor structure optimization and process parameter optimization, to lower CDO film tensile stress to below 30Mpa or even compressive stress.


REDACTED

| | | | |
|---|---|---|---|
| Haiying Fu | 8/13/03 Signature | Qingguo Wu | Signature |
| Dong Niu | 8/14/03 Signature | Inventor | Signature |
| Signature of 1st Witness / Date | 08/14/03 | Signature of 2nd Witness / Date | 8/14/03 |

# INVENTION DISCLOSURE

Novellus Systems, Inc.

Title of Invention: **Methods for producing Low-k OSG Film of low tensile stress**

Date this form was completed: 08/04/2003 

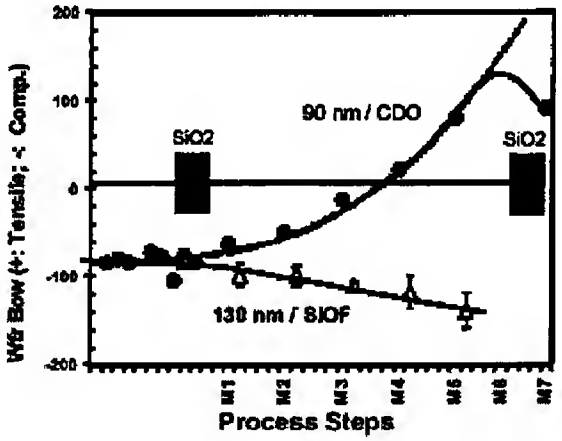


**Figure 1.** Wafer level stress as a function of process steps for 90 nm technology and 130 nm SiOF technology. Note that the tensile stress development in CDO stacks is offset by the compressive stress of the oxide layer at the top.

1. The tensile stress of low k film will be lowered through film densification
2. To achieve densification while maintaining low k value, precursor structure optimization is suggested.
3. To achieve densification while maintaining low k value, process conditions need to be optimized to improve crosslinking to enhance Si-$CH_2$-Si bonding content
4. Densified film with high Si-$CH_2$-Si content will have low stress and high hardness/modulus, thus better cracking resistance.

| | | | |
|---|---|---|---|
| Haiying Fu | Signature | Qingguo Wu | Signature |
| Dong Niu | Signature | Inventor | Signature |
| 08/14/03 | | 8/14/03 | |
| Signature of 1st Witness / Date | | Signature of 2nd Witness / Date | |

5. Percursor optimization includes more methyl groups in the precursor and preferred structures.
6. Process optimization includes process conditions to improve –CH3 incorporation in the film and to enhance crosslinking of –CH3 groups to form Si-CH2-Si matrix besides the existing Si-O-Si cage structure.

**Technical Contents**

The CDO film was deposited by using plasma enhanced CVD (PECVD) technology. Chemical precursor(s) with carrier gas such as $CO_2$ was introduced into a vacuum chamber, where RF plasma was ignited to polymerize the precursor and CDO was deposited onto a substrate. The suitable precursors include multiple siloxanes, such as tetramethylcyclotetrasiloxane (TMCTS), octamethylcyclotetrasiloxane (OMCTS), methyl-dimethylsiloxane (M-DMOS), and trimethyl-methylsiloxane (TM-MOS). Other suitable precursors include alkylsilanes, such as 4MS, TMSA, BTMSA, vinyltrimethylsilane (VTMS, $SiC_5H_{12}$), hexamethyldisilane (HMDS, $Si_2C_6H_{18}$). Further suitable precursors include the mixture of siloxane and alkylsilane.

The stress of CDO in an unoptimized process conditions was generally >50 Mpa with a typical value in the range between 60Mpa and 90 MPa. In this invention, we described the method on how to low the film stress through optimizing precursor and process conditions.

To reduce the film tensile stress, it is desired that the CDO film as deposited increase in its density while k value remain the same, e.g. by applying low frequency power and incorporating more carbon content and carbon associated bonding structures. Since methyl or

methylene group has a low polarizability, thus its increase in content in the deposited film will not have significant adverse impact on the dielectric constant, which is a crucial evaluation measure of a CDO film. The increase in carbon content incorporated in the film will increase film refractive index and density, and hence lower the tensile stress of the film.

It is also desired that the process deposition condition be optimized to enhance/promote the crosslinking of methylene group incorporated in the film to form Si-$CH_2$-Si structure. Without this crosslinking, the film mechanical strength will generally low due to the fact that an increase in content of methyl group $CH_3$ as a terminating group in the CDO film will reduce the bonding density per volume thus the bonding integrity of the film. With the crosslinking of methylene group, the Si-CH2-Si bonds are formed to strengthen the existing Si-O-Si cage structure. As a result, the mechanical strength, or the toughness, of the as deposited film will remain intact. The toughness is a measure of the resistance of a film against cracking propagation once the cracking is initiated. The crosslinking of Si-$CH_3$ groups will not increase the C content of the film, while Si-O-Si structure is still dominating the film composition to maintain a low dielectric constant. This ensures that the etching characteristic of the film as deposited should not be significantly altered.

The formation of Si-$CH_2$-Si is evident by FTIR spectra of the as deposited film. Figure 2 shows that one film with higher refractive index has bigger peak (see inset of Figure 2) assigned to bending of C-H in Si-$CH_2$-Si crosslinks although the k values of film a and b are the same.

Haiying Fu Signature

Qingguo Wu Signature

Dong Niu Signature

Inventor Signature

08/14/03

Signature of 1st Witness / Date

8/14/03

Signature of 2nd Witness / Date

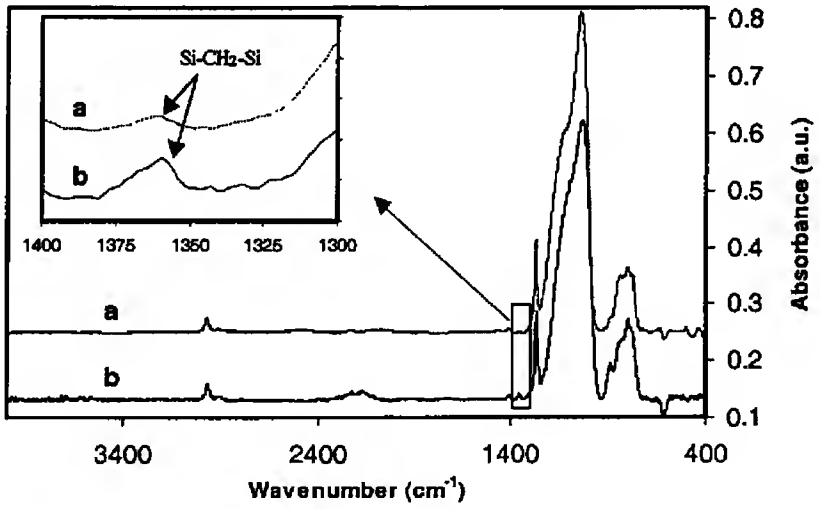


**Figure 2. FTIR spectra of two CDO films: "a" and "b" with the same k = 2.94 and hardness H~2.02GPa. The difference in the Si-CH2-Si results in difference in other properties of these two films, including RI and film stress.**

The formation of Si-$CH_2$-Si bonding structure is also evident by refractive index of the as-deposited film. Table below summarized the properties of Film "a" and Film "b". Though k value and hardness are similar for these two films, the difference in film bonding structure, especially Si-$CH_2$-Si bond as shown in Figure 2, results in that the two films has significantly different refractive index (RI) and in-film stresses. Film "b" of higher refractive index has a lower tensile stress than film "a". The additional bonding in film "b" also improved its cracking limit over film "a".

Haiying Fu Signature

Qingguo Wu Signature

Dong Niu Signature

Inventor Signature

08/14/03

Signature of 1st Witness / Date

8/14/03

Signature of 2nd Witness / Date

| | K | H (GPa) | RI | Stress (MPa) | Cracking Limit (um) |
|---|---|---|---|---|---|
| Film "a" | 2.94 | 2.02 | 1.3913 | 88.5 | 1.5 μm |
| Film "b" | 2.94 | 2.06 | 1.4404 | 67.9 | 4.3um |

Figure 3 shows more data to illustrate the relationship of as deposited film stress and refractive index. RI is used as a measure of volumetric content of Si-C-Si in the film. The tensile stress decreases below 50MPa as RI or content of Si-C-Si bonds increases.

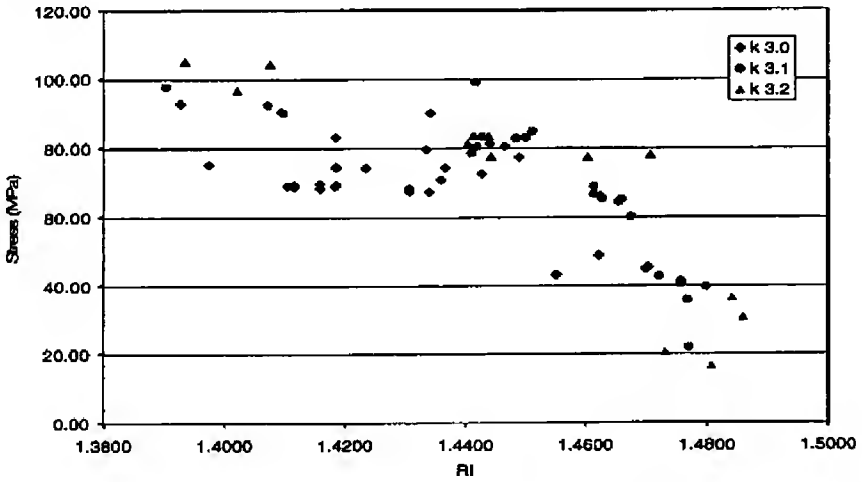


**Figure 3. Stress is plotted as a function of refractive index of as deposited film for different k values. For all k values, stress decreases as refractive index increases.**

To optimize the as deposited film bonding structure to lower the film tensile stress, two key areas are found to be critical.

Haiying Fu Signature

Qingguo Wu Signature

Dong Niu Signature

Inventor Signature

Signature of 1st Witness / Date 08/14/03

Signature of 2nd Witness / Date 8/14/03

1. Precursor selection. Precursor structure has a significant impact on the structure of the film deposited. The precursor structure prefers containing more $-CH_3$ group as shown in the Figure 4. More –CH3 group in the precursor will enhance CH3 content incorporated in the deposited film to increase as-deposited film density thus lower the film stress. Process conditions are further optimized to promote certain bonding formation such as $Si-CH_2-Si$ to further strengthen the film mechanical property and lower film stress. .

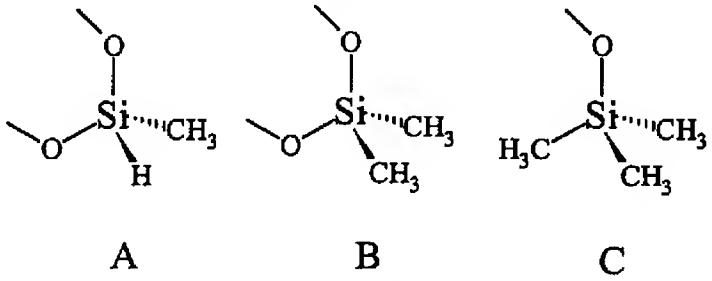


**Figure 4. Precursor structures.**

2. Process optimization. Besides precursor structure optimization, process conditions were optimized to improve the incorporation of $-CH_3$ group and to enhance the densification of the as-deposited film.

   One method to improve the incorporation of $-CH_3$ group in the film is to apply lower deposition temperature. Figure 5 illustrates how the film stress varies with the deposition temperature. Near k=3.0, the 400°C process yielded a stress around 45 MPa. A deposition temperature decreases, the film stress decreases rapidly. At deposition temperature of 300°C,

the film stress is around 33 MPa with k value of 2.87, significantly lower than the stress at 400°C.

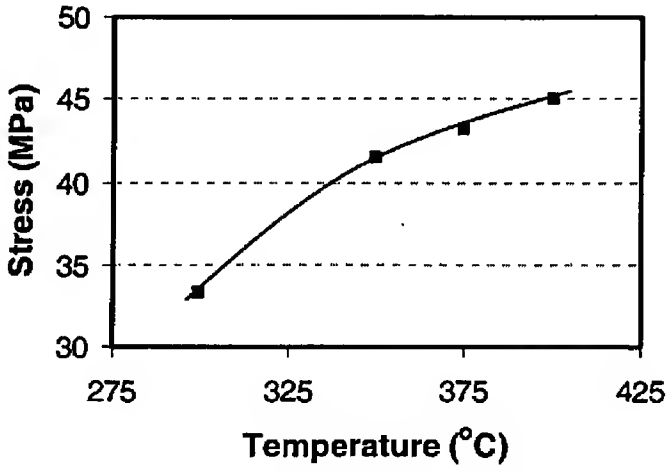


**Figure 5. Stress is plotted as a function of deposition temperature of the as deposited films.**

The other method to densify the film is to increase the ion bombardment during the PECVD deposition. The increased ion bombardment will not only improve –CH3 incorporation but also enhance the bonding structure of the as-deposited film.

The increased ion bombardment can be achieved by increasing low Frequency (LF) RF power in a dual frequency process. As shown in Figure 6, the film stress decreases linearly as LFRF power percentage in total RF power increases. A negative stress i.e. compressive stress can be achieved at a high percentage of LFRF power.

Haiying Fu Signature | Qingguo Wu Signature

Dong Niu Signature | Inventor Signature

08/14/03 | 8/14/03

Signature of 1st Witness / Date | Signature of 2nd Witness / Date

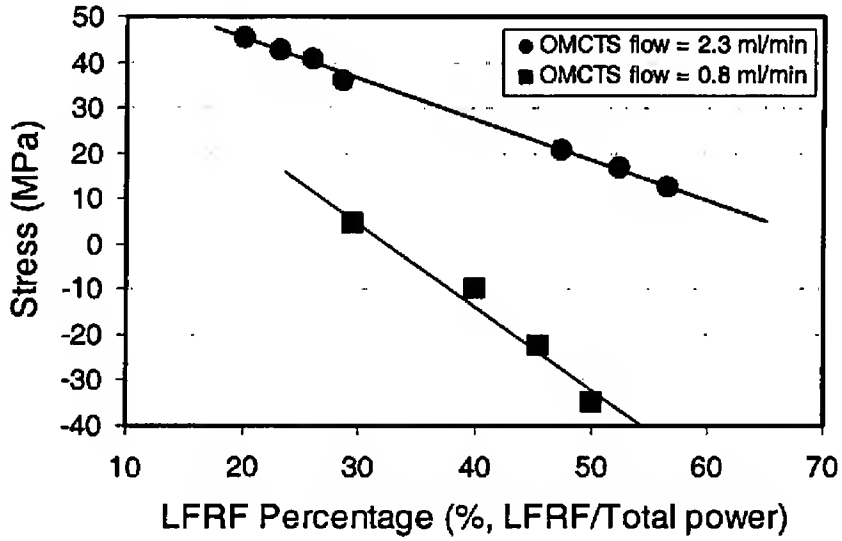


**Figure 6. Stress is plotted as a function of LF power of the as deposited films for different precursor flow of OMCTS =2.3ml/min (circles) and OMCTS=0.8ml/min(squares).**

Other methods to increase ion bombardment during film deposition include: a) lowering deposition pressure; b) varying showerhead gapping; c) applying pulsed HFRF power, i.e. a HFRF power pulsed at a certain duty cycle.

**REDACTED**

Haiying Fu Signature

Qingguo Wu Signature

Dong Niu Signature

Inventor Signature

Signature of 1st Witness / Date 08/14/03

Signature of 2nd Witness / Date

# INVENTION DISCLOSURE

Novellus Systems, Inc.

Title of Invention: **Methods for producing Low-k OSG Film of low tensile stress**

Date this form was completed: 08/04/2003 Page 10 of 10

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A low tensile stress of a CDO film will significantly lowers the total tensile stress of the integrated stack, reduces the failure rate due to the high tensile stress, and improves the production yield.

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| | |
|---|---|
| Haiying Fu Signature | Qingguo Wu Signature |
| Dong Niu Signature | Inventor Signature |
| 08/14/03 | 8/14/03 |
| Signature of 1st Witness / Date | Signature of 2nd Witness / Date |

# EXHIBIT B

NOVELLUS

# Interoffice Memorandum

To: Haiying Fu

From: Gordon Q. Wu

Re: k<2.6 C&F and Less Stress HMS Coral k2.9 Date: 06/25/2003

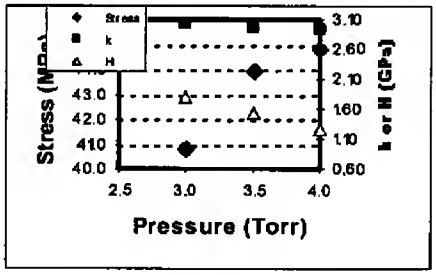
- **This Week's work done:**

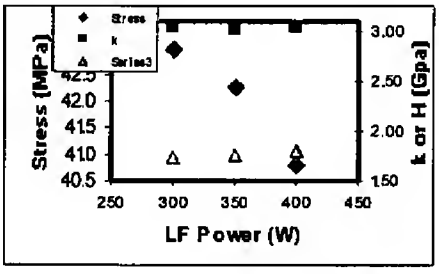
**REDACTED**

b) **Less Stress HMS CORAL k2.9-3.0**

- *A full SVTs based on baseline recipe, HF600 W, LF 400 W, CO2 5000 sccm and TMCTS 4 ccm.*

  - SVT on **pressure** was done. The results show that stress decreases with decreasing pressure while k increases as pressure decreases, which suggests that increasing SiO concentration contributes to the decreasing stress. Hardness increases with decreasing pressure



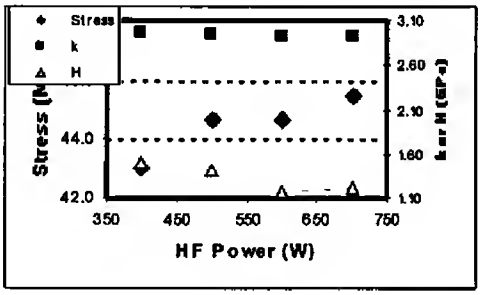






Confidential

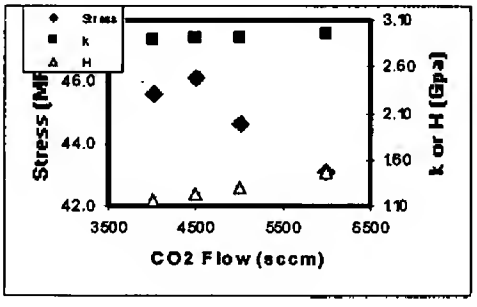
- SVT on **LF power** was done. The results as shown above presents that LF power doesn't affect k value under the experimental range, however, stress decreases as increasing LF power, which shows LF power is a important effect factor to stress. Hardness was improved through adding more LF power while keep k around the same.

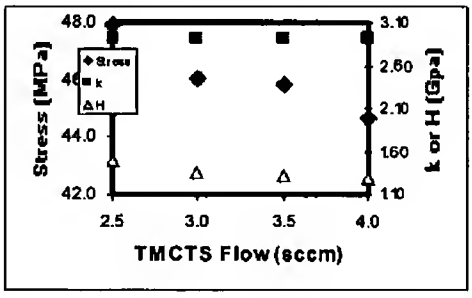
- SVT on **HF power** was done. As shown following figure, HF power has different effect trend to stress compared with LF power. Stress increases with increasing HF power while k value decreases as HF power increases, which is similar to our previous experimental results we observed during development of Process B. Therefore low HF power leads low stress but bad non-uniformity. Hardness increases with decreasing HF power.




- SVT on **CO2 flow rate** was done. Stress decreases with increasing CO2 flow rate while k value and hardness increase with increasing CO2 flow rate. Therefore, high CO2 can leads low stress but high k as well. It could be believed that high SiO attributes to low stress.

- SVT on **TMCTS flow rate** was done. Stress decreases with increasing TMCTS flow rate while k value decreases slowly or doesn't change in some range with increasing TMCTS flow rate, which suggests that TMCTS flow rate is another main effect factor to stress. Hardness increases with decreasing TMCTS flow rate.



- Summary - *Some recipes for stress <50 and <30 MPa.*

**Stress < 50, and k ~2.9-3.0, H ~ 1.5-1.8**
*T 350 °C

| Wafer ID | Press Torr | HF W | LF W | CO2 sccm | TMCTS ccm | DR A/min | NU,% 49-pt-3 | RI Optic | k (Hg) Optic | Stress MPa | H Gpa | FTIR SiCH3/SiO (%) | CL um |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TM3 | 4.0 | 600 | 400 | 5000 | 2.5 | #REF! | 1.54<br>1.36 | 1.435<br>1.435 | **2.92** | **47.94** | 1.49 | 3.51 | **<6.3** |
| P3 | 3.0 | 600 | 400 | 5000 | 4.0 | #REF! | 1.79<br>1.49 | 1.4599<br>1.4614 | 3.04 | 40.81 | 1.80 | 3.27 | >6.3 |

**Stress < 30, and k ~2.9-3.0, H ~ 1.2-1.4**
*T 300 °C

| Wafer ID | Press Torr | HF W | LF W | CO2 sccm | TMCTS ccm | DR A/min | NU,% 49-pt-3 | RI Optic | k(Hg) Optic | Stress MPa | H Gpa | FTIR SiCH3/SiO (%) | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2CO2 | 3.0 | 600 | 400 | 7000 | 5.0 | #REF! | 1.95<br>1.71 | 1.453<br>1.457 | **3.03** | **26.49** | 1.29 | 3.81 | **>5.8** |
| 3HF1 | 3.0 | 400 | 400 | 7000 | 5.0 | #REF! | 2.05<br>1.79 | 1.459<br>1.46 | 3.05 | 24.09 | 1.39 | 3.75 | >5.8 |

**REDACTED**

# EXHIBIT C

Novellus Systems, Inc.
4000 North First Street
San Jose, CA 95134
TEL: (408) 943-9700
FAX: (408) 943-3422

September 22, 2003

Jeffrey K. Weaver, Esq.
Beyer Weaver & Thomas, LLP
2030 Addison Street, Seventh Floor
Berkeley, CA 94704

NOVELLUS

Dear Jeff,

Please prepare and file formal U.S. patent applications for Novellus Docket Nos.:

1) **NVLS-000802** entitled " REDACTED ".

2) **NVLS-002867** entitled " REDACTED ".

3) **NVLS-002872** entitled " REDACTED ".

4) **NVLS-002875** entitled " REDACTED ".

5) **NVLS-002876** entitled " REDACTED ".

6) **NVLS-002880** entitled " REDACTED ".

7) **NVLS-002882** entitled " REDACTED ".

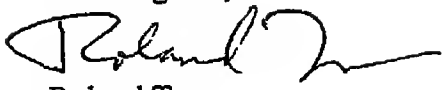
8) **NVLS-002887** entitled " REDACTED ". NOTE: Combine with NVLS-002886 for one application. NVLS-002887 will be the official Novellus docket number for this application.

9) **NVLS-002888** entitled " REDACTED ".

10) **NVLS-002889** entitled "Methods for Producing Low-k OSG Film of Low Tensile Stress".

11) **NVLS-002893** entitled " REDACTED ".

Best Regards,



Roland Tso
Intellectual Property Counsel

# EXHIBIT D

NOVELLUS

# Interoffice Memorandum

To: Haiying Fu

From: Gordon Q. Wu

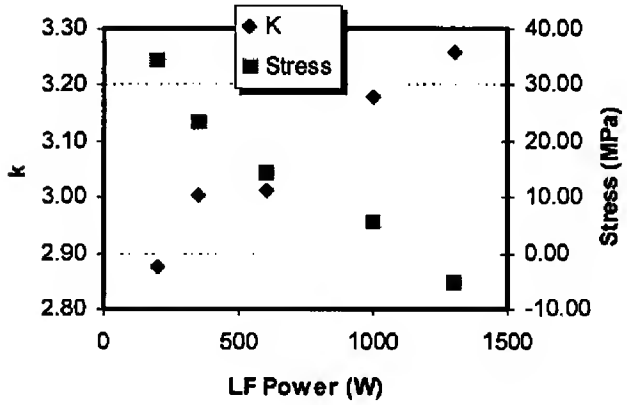
Re: k2.0-2.5 and Compressive low-k C&F Date: 10/29/2003

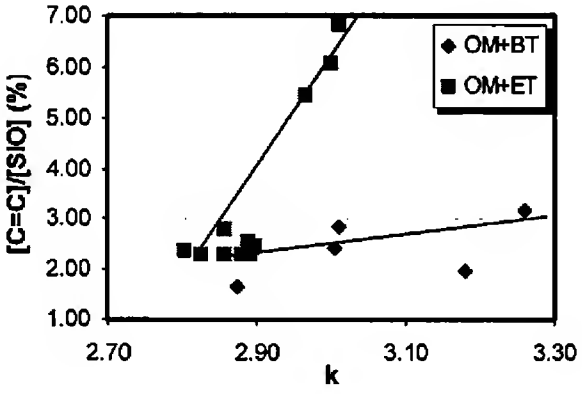
- **This Week's work done:**

**REDACTED**

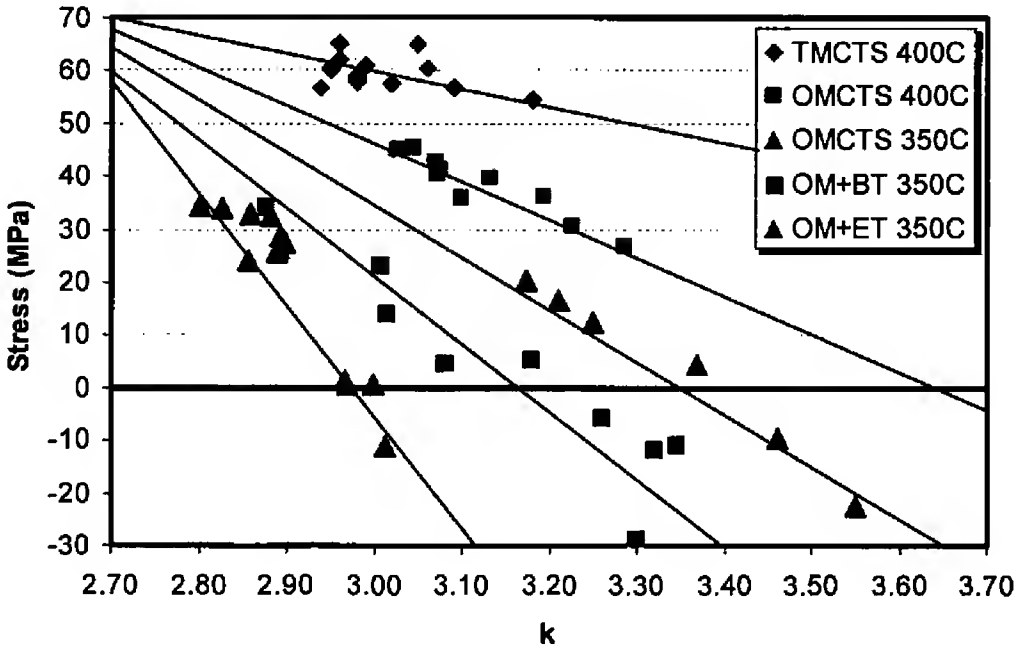
**200mm low stress OSG C&F**

- A k3.0 with compressive stress has been obtained using OMCTS+ETMS. In order to achieve lower stress, especially, k2.7 film, OMCTS+BTMSA was explored.
- Basically, both stress and k decrease after added BTMSA, which is very similar to OMCTS+ETMS. As shown in following figure. A SVT on LF power was done. K decreases with decreasing LF power while stress increases with decreasing LF power.
- FTIR show that triple carbon-carbon bond concentration increases with increasing k value for both OMCTS+ETMS and OMCTS+ETMS, however, OMCTS provide more triple C-C bond and lower stress.




- Films' stress and k for the OMCTS+BTMSA films were added to the following figure. OMCTS+ BTMSA provide lower stress compared with OMCTS but higher stress than those of OMCTS+ETMS films.



- **Plan for next week.**

  a) **To tune Dep trend for k2.5 film at 285C and ENB flow at 0.7ccm.**
  b) **To explore BTMSA only process to see if can get lower stress k2.7 film..**
  c) **Customer support if need.**

# EXHIBIT E

NOVELLUS

# Interoffice Memorandum

To: Haiying Fu

From: Gordon Q. Wu

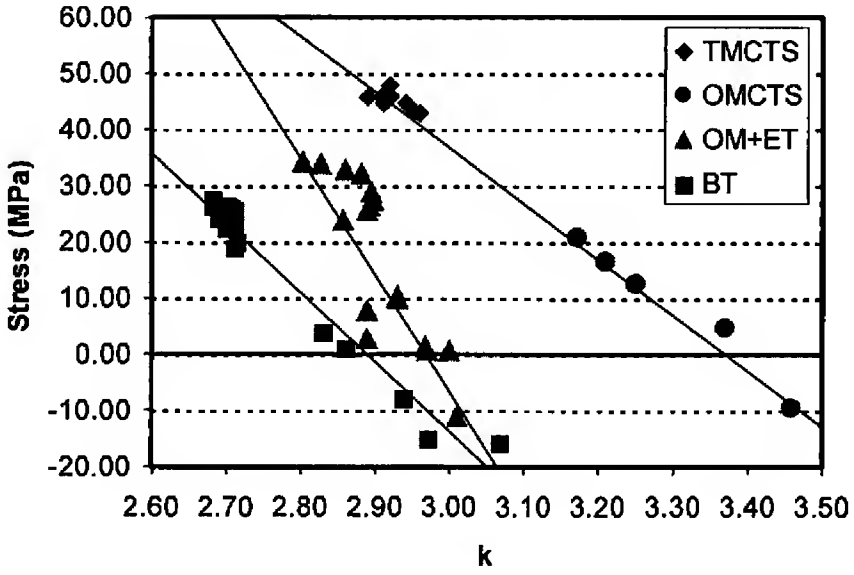
Re: k2.0-2.5 and Low Stress OSG C&F Date: 11/12/2003

- **This Week's work done:**

**REDACTED**

**200mm low stress OSG C&F** **REDACTED**

- To achieve lower stress and k, some more studies have been done. It shows that lower stress and lower k can been obtained from BT. The slope of BT is very different from OM+ET, which suggests that more functional groups can been incorporated to the OSG matrix at lower k value range under these conditions. A film with **k2.69**, stress **24.3 MPa** and **CL >5um** was achieved. In addition, **k2.86 film has shown 0 stress.**




- More detail work on k around 2.7 has been done. SVTs on HF, LF, pressure and BT:
  - The results show that k decreases with increasing HF power while stress slightly increases with increasing HF power.
  - However, k increases with increasing LF power while stress decreases with increasing LF power.



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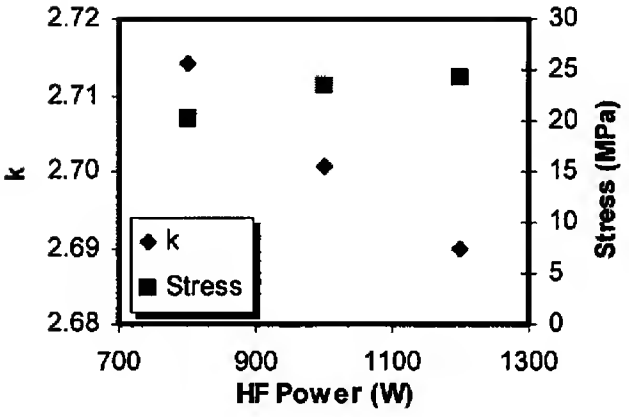
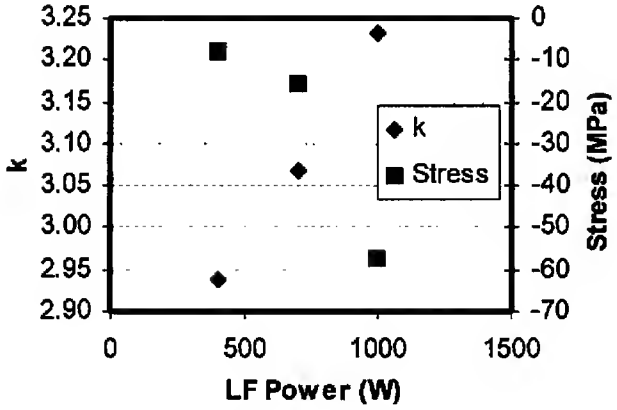
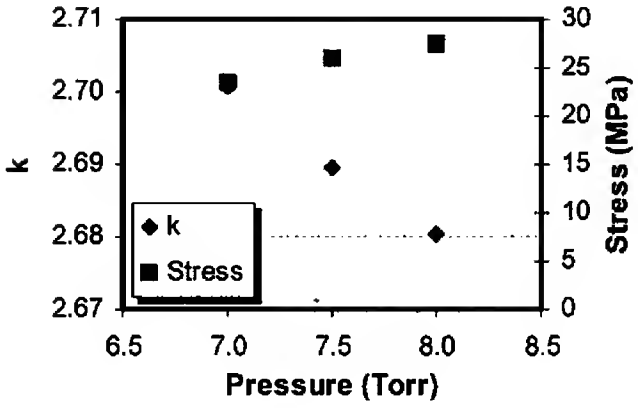
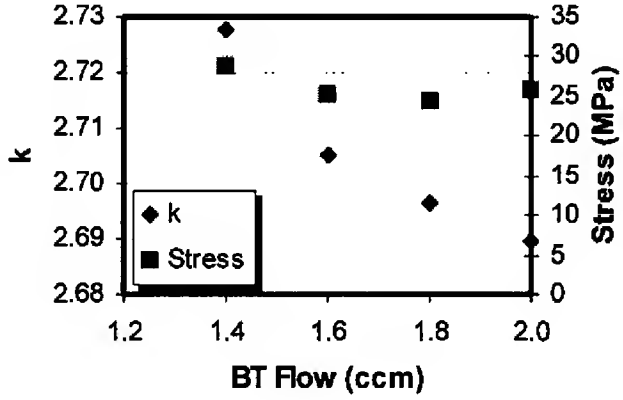
- As shown in following figure, k decreases with increasing pressure and stress increases with increasing pressure.



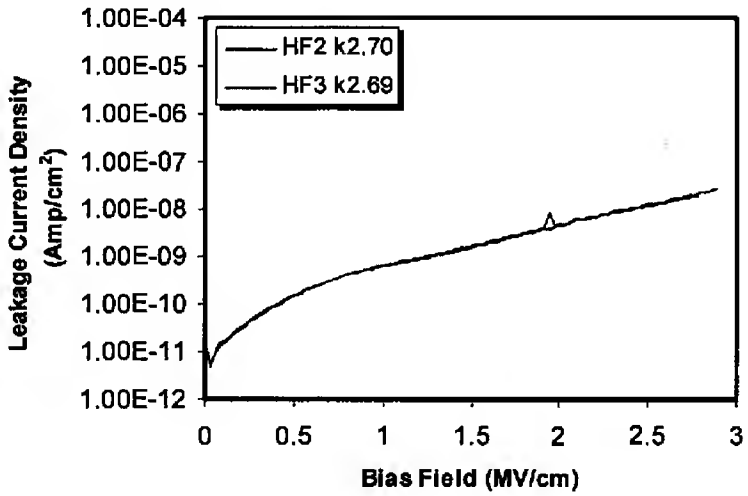




- Both k and stress decrease with increasing BT flow rate at first, which is similar to TMCTS based film.




- Leakage current measurements for k2.70 and 2.69 films have been down. It shows that there are low leakage current (6.5E-10 Amp/cm2 at 1 MV), which even lower than that of PORA (7.6E-10 Amp/cm2).

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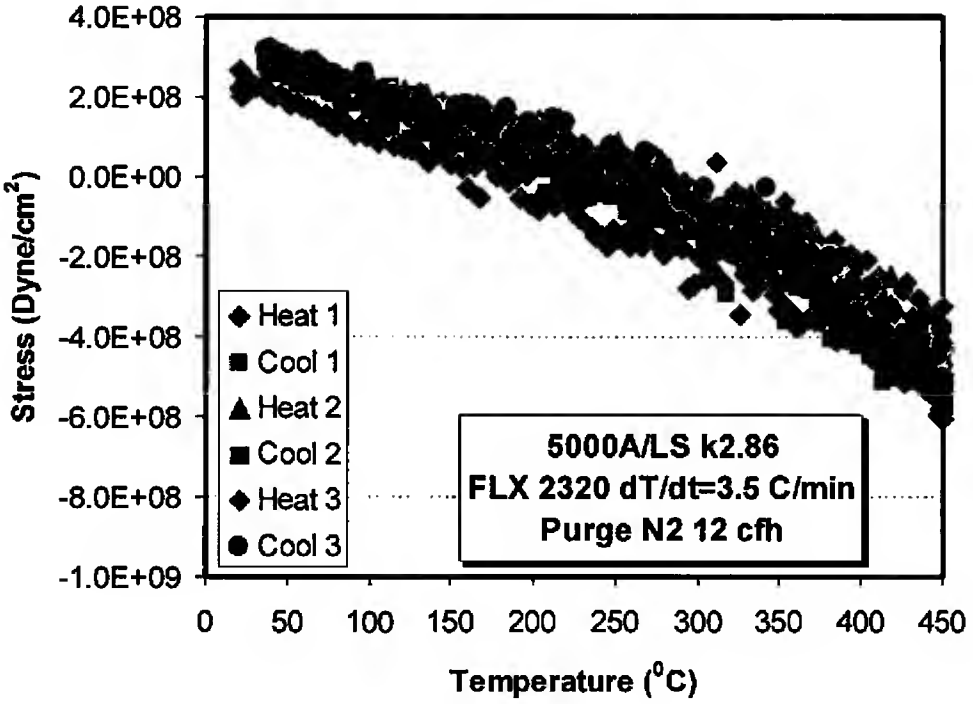
- Stress hysteresis of k2.86 film deposited by OM+ET has been done. It shows that stress decreases with increasing temperature.




- **Plan for next week.**

  a) **To explore BTMSA single frequency process.**
  b) **To explore BT+ENB single frequency process.**
  c) **Customer support if need.**

# EXHIBIT F

NOVELLUS

# Interoffice Memorandum

To: Haiying Fu

From: Gordon Q. Wu

Re: Low Stress OSG C&F Date: 12/03/2003

- **This Week's work done:**

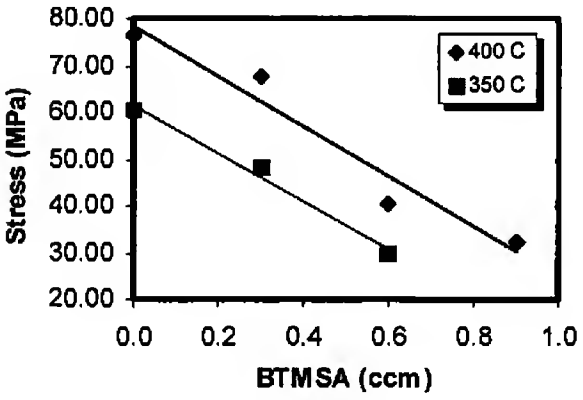
**200mm k2.2-2.5 C&F (Gordon/Tim)**

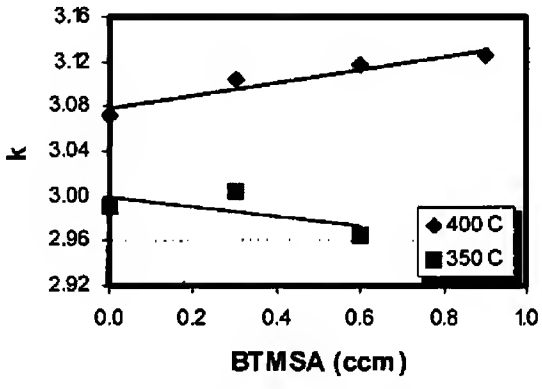
**REDACTED**

**200mm low stress k2.5-2.7 C&F (Gordon/Tim)**

**TMCTS+BTMSA dual frequency process**

- TMCTS+BTMSA single frequency process already showed lower stress and lower k value (k2.6 film) compared with TMCTS only process. To explore TMCTS+BTMSA dual frequency process and achieve k2.5-2.9 films with low stress, SVT on BTMSA have been done.
- The results show that stress decreases sharply after addition of BTMSA both at temperature 400C and 350C. k value decreases slightly with increasing BTMSA flow rate for 350 C deposition. It is unclear that why k increases slightly at 400C deposition which is different from the process at 350C and OMCTS+BTMSA process as well. SVTs on LF, HF and P will be done next week.



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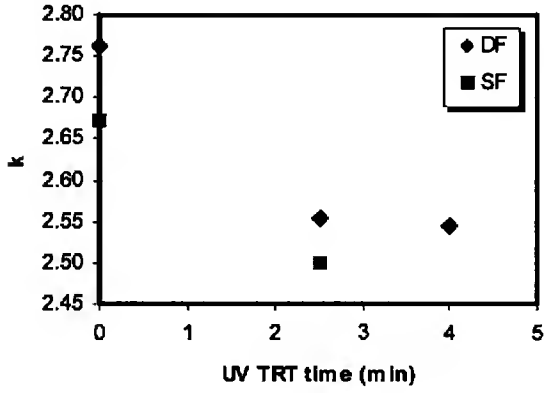
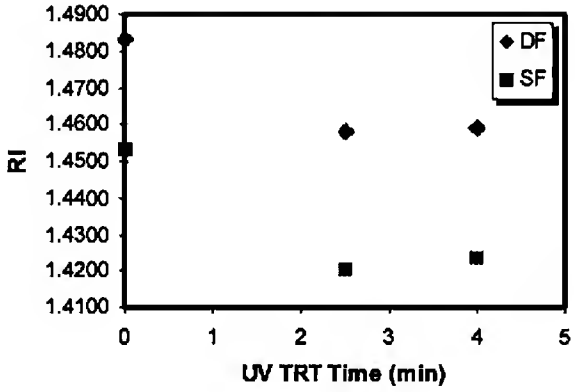
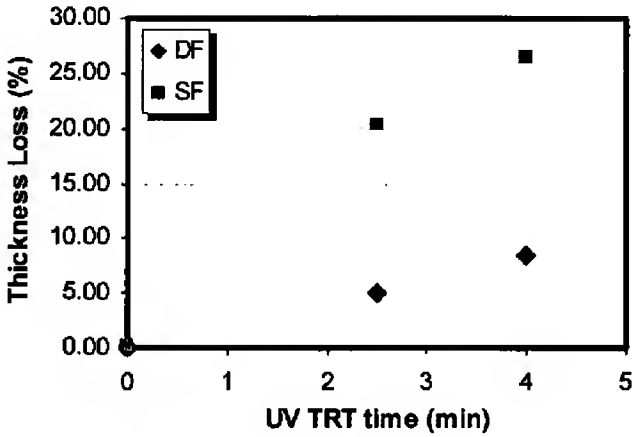
**BTMSA only process**

- We are exploring the possibility to achieve low stress k2.5 without porogen. The advantages for no porogen process: 1. May get higher hardness; 2. Good repeatability for UV station. One choice of them is to use BTMSA or ETMS only process. It seems that these films obtained from BTMSA or ETMS process contains more small polymer molecules during deposition. These small polymer molecules are easily removed if using UV TRT. Some tests have been done.
  - Two different films were used for UV TRT. One is BTMSA film obtained from dual frequency and the other film obtained from single frequency process.
  - As shown in following figure, k value decreases about 0.2 for both films after UV TRT for 2.5 min (use old quartz plate and distance 5 inch). The k value already reached the 2.5 level.




  - RI decreases after UV TRT for both films, which indicates that more free space have been created.
  - Thickness loss for dual frequency process film was much smaller than that of those processes with porogen. However, the film obtained from has very high thickness loss due to too soft.
  - Further exploration will be carried out next week.

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- **Plan for next week.**

  a) **To explore UV TRT for films obtained from BTMSA dual frequency process.**
  b) **To explore MTES process.**
  c) **To obtain low stress k2.85 recipe for integration test.**
  d) **Customer support if need.**

# EXHIBIT G

| CLIENT | DOCKET | DATE | ATTY | INVOICE | HOUR | RATE | AMOUNT | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|
| NOVL | P091 | 9/23/2003 | JKW | 21930 | 0 | | | Review invention disclosure for content and bar dates; input new patent application |
| NOVL | P091 | 9/29/2003 | JB | 21930 | 0 | | | Reviewed inventor disclosure. |
| NOVL | P091 | 12/8/2003 | JB | 21930 | 2.8 | | | Preparation for meeting. Inventor disclosure phone conference. Discussion with JKW as to how to proceed with patent application. |
| NOVL | P091 | 12/8/2003 | JKW | 21930 | 4 | | | Telephonic invention disclosure meeting; prepare patent application outline and claims |
| NOVL | P091 | 12/16/2003 | JB | 21930 | 5.3 | | | Prepared patent application. |
| NOVL | P091 | 1/5/2004 | JB | 21930 | 0 | | | Prepared patent application. |
| NOVL | P091 | 1/6/2004 | JB | 21930 | 2.3 | | | Prepared patent application. |
| NOVL | P091 | 1/7/2004 | JKW | 21930 | 0 | | | Prepare apparatus figure with Joe Bond |
| NOVL | P091 | 1/8/2004 | JB | 21930 | 9.2 | | | Prepared patent application. |
| NOVL | P091 | 1/12/2004 | JB | 21930 | 0 | | | Prepared patent application |
| NOVL | P091 | 1/26/2004 | JKW | 21930 | 3.25 | | | Patent application preparation |
| NOVL | P091 | 1/27/2004 | JKW | 21930 | 0 | | | Patent application preparation |
| NOVL | P091 | 1/28/2004 | JKW | 21930 | 0 | | | Patent application preparation |
| NOVL | P091 | 2/3/2004 | JKW | 21930 | 1 | REDACTED | REDACTED | Patent application preparation |
| NOVL | P091 | 2/4/2004 | JKW | 21930 | 0 | | | Patent application preparation |
| NOVL | P091 | 2/5/2004 | JKW | 21930 | 0 | | | Finalize draft of patent application |
| NOVL | P091 | 2/5/2004 | JB | 21930 | 2.25 | | | Finalized informal drawings for review. Sent out draft and figures for inventor review. |
| NOVL | P091 | 2/10/2004 | JB | 21930 | 3.25 | | | Prepared patent application. |
| NOVL | P091 | 2/11/2004 | JB | 21930 | 1.75 | | | Conference with inventor and preparation of second draft of application. |
| NOVL | P091 | 2/26/2004 | JKW | 21930 | 0 | | | Patent application preparation |
| NOVL | P091 | 2/27/2004 | JB | 21930 | 2.4 | | | Prepared patent application. |
| NOVL | P091 | 2/28/2004 | JKW | 21930 | 0 | | | Patent application preparation |
| NOVL | P091 | 3/1/2004 | JKW | 21930 | 0 | | | Patent application preparation |
| NOVL | P091 | 3/11/2004 | JKW | 21930 | 0 | | | Review final round of comments and correspond with inventors re same |
| NOVL | P091 | 3/29/2004 | JB | 21930 | 0.75 | | | Sent formal papers and final draft to inventors. |
| NOVL | P091 | 2/3/2004 | PATC | 21930 | | | | NERAC Patent Copies (Dec 2003) |
| | | | | | | | | |
| NOVL | P091 | 4/7/2004 | JB | 22582 | 0 | | | Preparation of Assignment and recordation cover sheet. Recordation of Assignment in U.S. PTO. |
| NOVL | P091 | 3/29/2004 | FEDD | 22582 | | | | FedEx Delivery Charge (1-673-84530)Laura Dean to David Mordo |
| NOVL | P091 | 3/29/2004 | FEDD | 22582 | | | | FedEx Delivery Charge (1-673-84530)Laura Dean to Haiying Fu |
| NOVL | P091 | 4/7/2004 | ADDC | 22582 | | | | Additional Claims Fee (#22097) |
| NOVL | P091 | 4/7/2004 | ADDC | 22582 | | | | Additional Claims Fee (#22098) |
| NOVL | P091 | 4/7/2004 | ASSI | 22582 | | | | Assignment Recordation Fee (#22097) |
| NOVL | P091 | 4/7/2004 | FILF | 22582 | | | | Filing Fees (#22097) |
| NOVL | P091 | 4/7/2004 | INDE | 22582 | | | | Independent Claims Fee (#22097) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NOVL | P091 | 7/14/2004 | JB | 24021 | 0 | | REDACTED | Preparation and filing of Information Disclosure Statement in the U.S. PTO with 5 references. |

# EXHIBIT H

BEYER WEAVER & THOMAS, LLP

INTELLECTUAL PROPERTY LAW

590 W. El Camino Real, Mountain View, CA 94040
Telephone: (650) 961-8300 Facsimile: (650) 961-8301
www.beyerlaw.com

March 29, 2004

*Via Federal Express*

Haiying Fu
**Novellus Systems, Inc.**
11155 Southwest Leveton Road
Tualatin, OR 97062

Re: U.S. Patent Application Entitled: METHODS FOR PRODUCING LOW-K CDO FILMS WITH LOW RESIDUAL STRESS
Your File: NVLS-002889
Our File: NOVLP091

Dear Haiying:

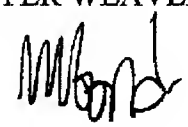
Thank you for your comments concerning the above-referenced patent application. We have now revised the application in accordance with your comments.

At this time it is necessary to have each inventor sign the enclosed standard forms. One form is a Declaration and Power of Attorney form, and the other form is an Assignment of rights to Novellus Systems, Inc. After the final read through of the patent application (assuming no additional changes are needed), please have each inventor read and then sign and date each of the enclosed forms by their name. **Afterwards, please return the application together with the executed documents so that we may file them with the U.S. Patent and Trademark Office.**

Finally, we would again like to remind you of our duty to disclose the most pertinent prior art of which you are aware to the Patent and Trademark Office. If you can think of any pertinent references or patents, or any similar existing technology, please let us know. The duty to disclose prior art continues until the patent actually issues; if you become aware of other prior art in the future, please let us know.

Best regards,

BEYER WEAVER & THOMAS, LLP



Joseph E. Bond

JEB/lmd
Enclosures